

Title: Results of International Space Station Vehicle Materials Exposed on MISSE-7B

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Materials samples were exposed to the low Earth orbit (LEO) environment as part of the MISSE-7B flight experiment for 18 months. Optical properties, thickness/mass loss, surface elemental analysis, visual and microscopic analysis for surface change are some of the techniques employed in this investigation. Where possible, the MISSE-7B results are compared to analyses from other LEO experiments. ISS materials currently flying on MISSE-8 are also discussed.



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B

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# Results of International Space Station Vehicle Materials Exposed on MISSE-7B

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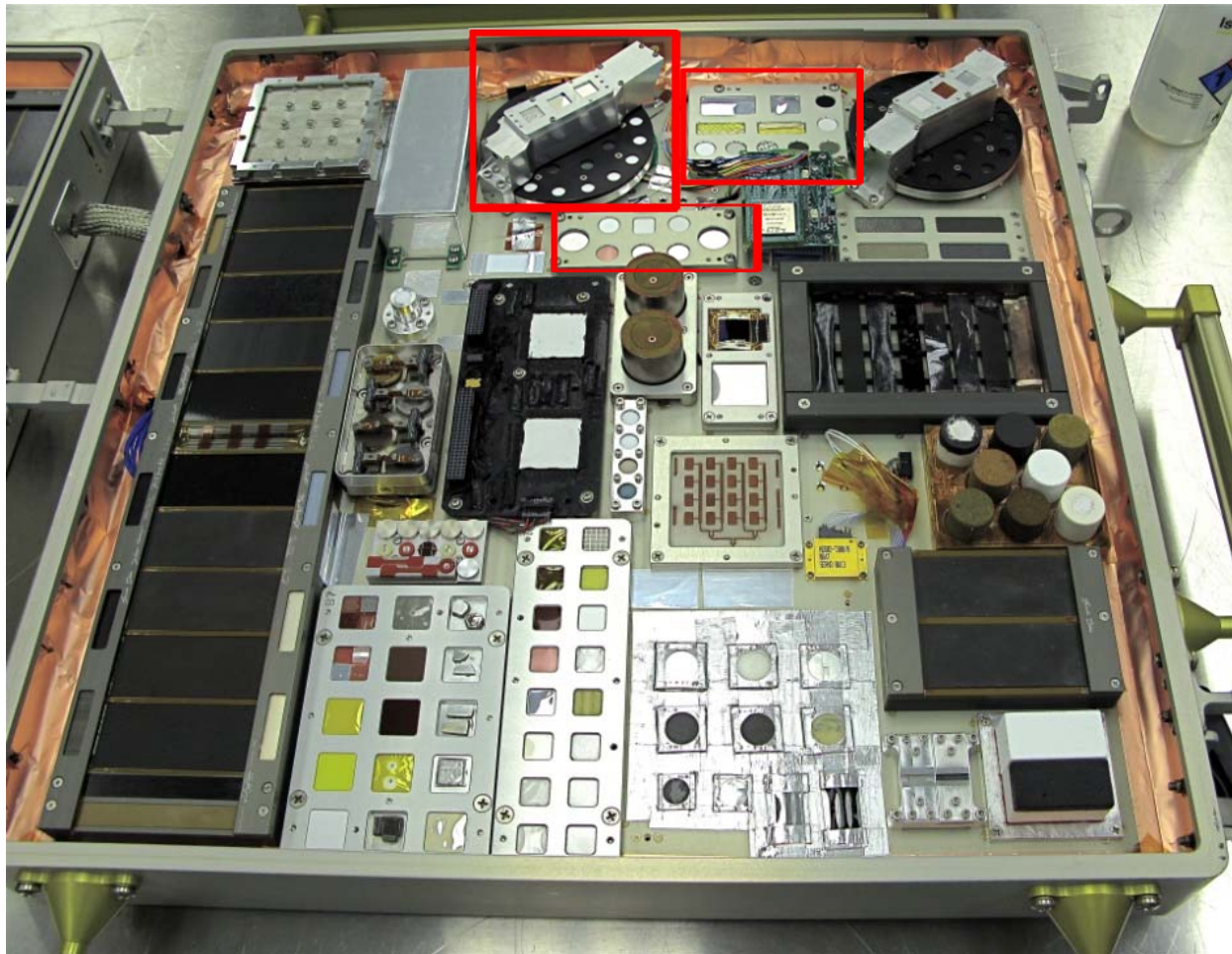
- **Background**
- **Results**
  - **Thermal control coatings**
  - **Anodized aluminum**
  - **Alodine**
  - **Multi-layer insulation materials**
  - **Polymeric materials**
- **Summary**



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## Location of samples on ram face

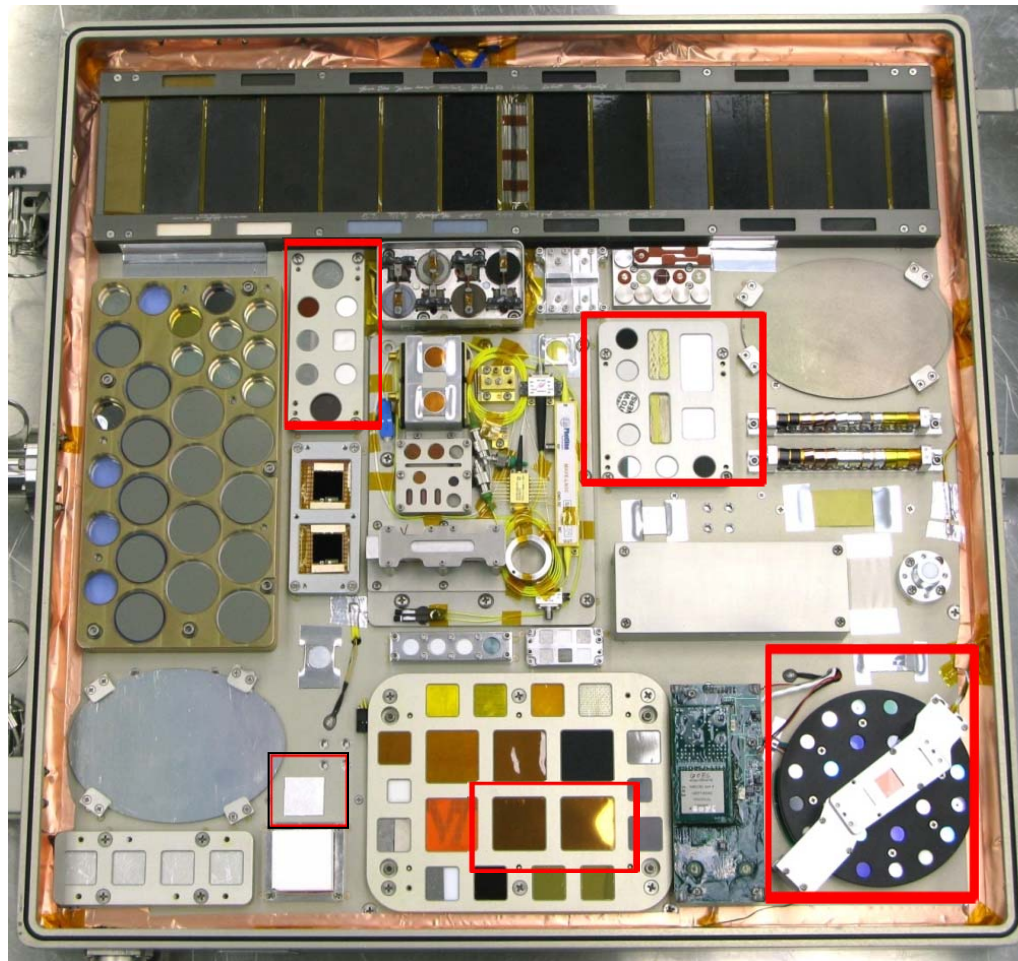




# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## Location of samples on wake face







# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- **Thermal Control Coatings**

- **AZ93 was flown as a bellwether for contamination and monitor for ISS radiator coating health.**
- **AZ400 is similar in performance to AZ93 but uses a low outgassing silicone binder.**
  - **Does not require controlled temperature and humidity when applying.**
- **AZ-2000-LSW and AZW/LAII – LSW are experimental organic versions of standard inorganic AZ-2000-IECW and AZW/LAII coatings, which have flown on previous MISSEs.**
- **RM-550-IB is known to be stable in UV, so was flown as a black backing for some of the carousel window samples.**
- **AZ3700 was developed specifically for  $\alpha$  and  $\epsilon$  close to 0.30 and as a protective/sacrificial film with 966 adhesive backing.**

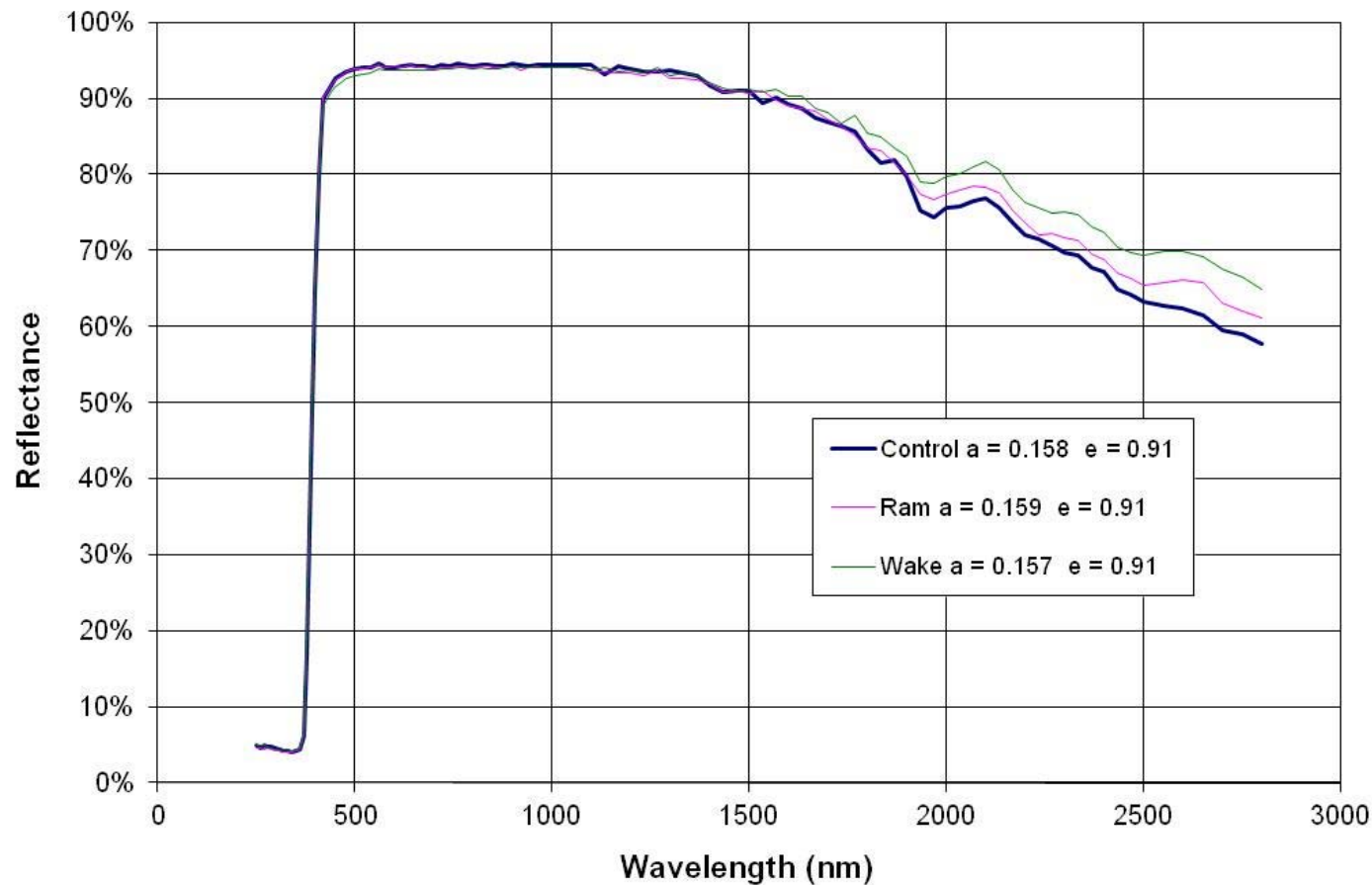


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



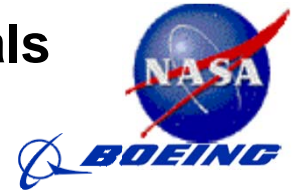
- Thermal Control Coatings

## MISSE-7B AZ93



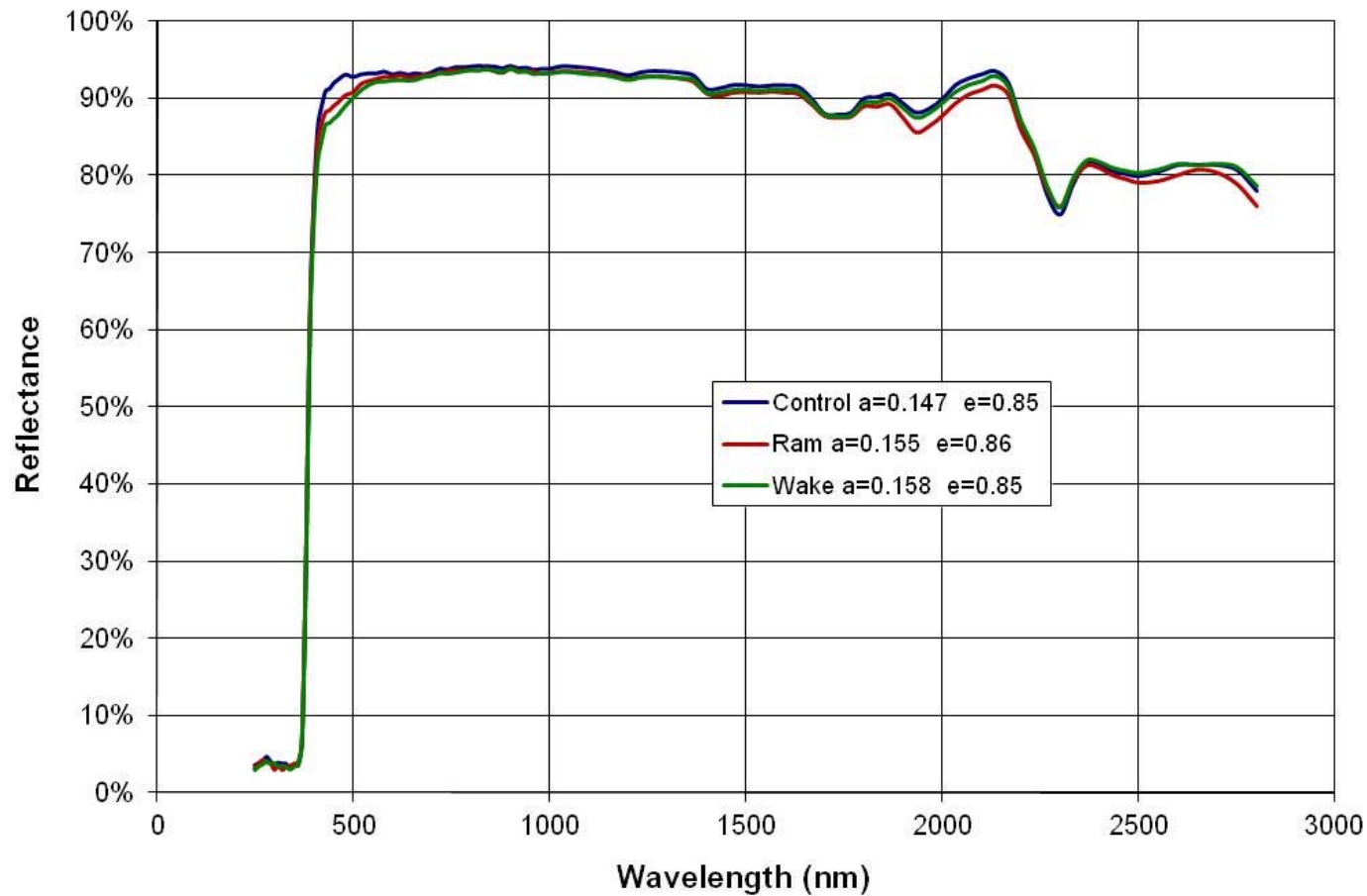


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Thermal Control Coatings

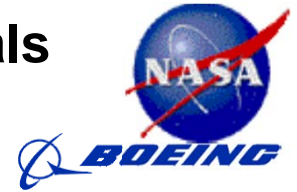
## MISSE-7B AZ400





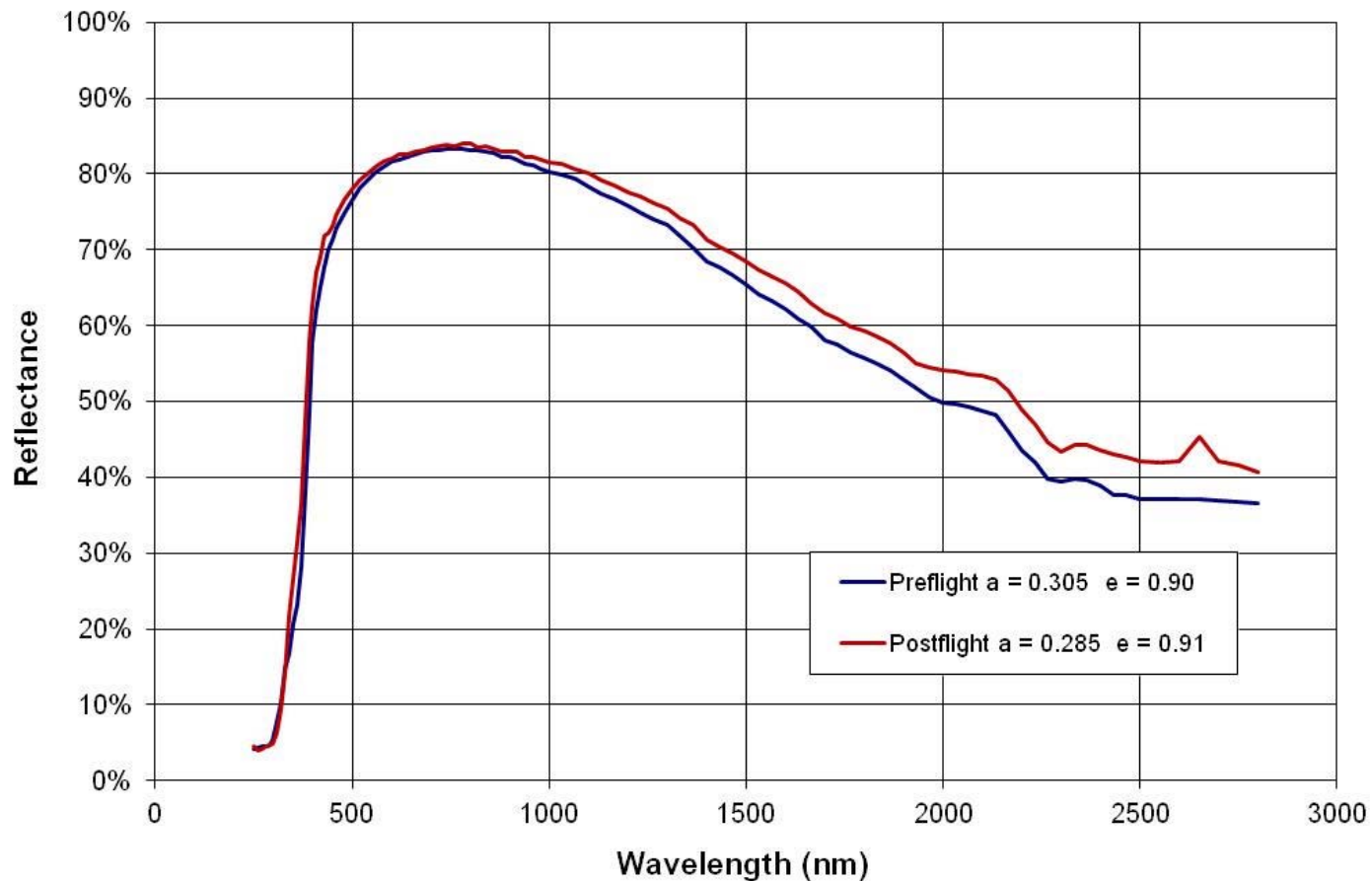


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Thermal Control Coatings

## MISSE-7B AZ2000-LSW



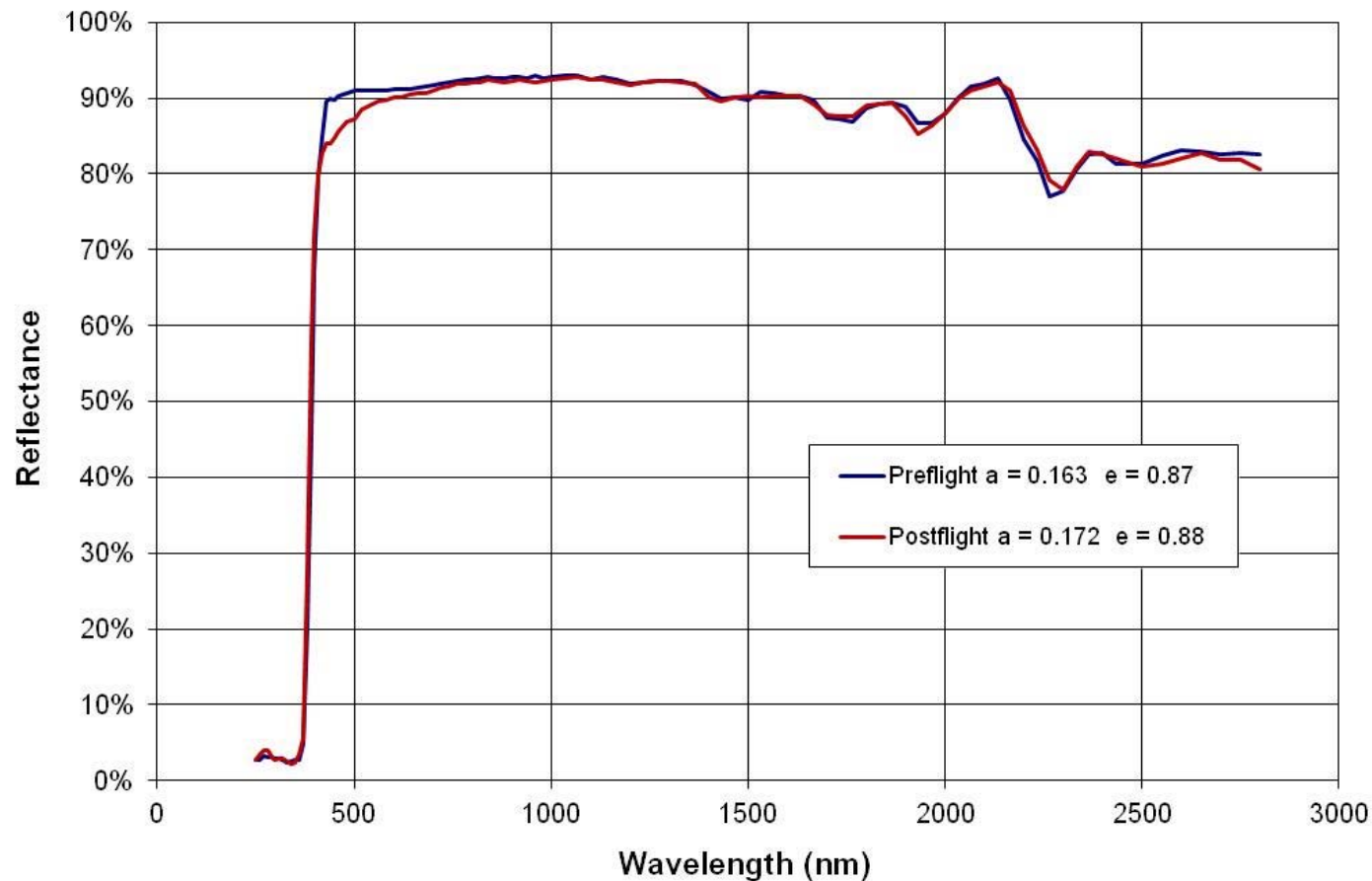


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Thermal Control Coatings

## MISSE-7B AZW/LAII - LSW



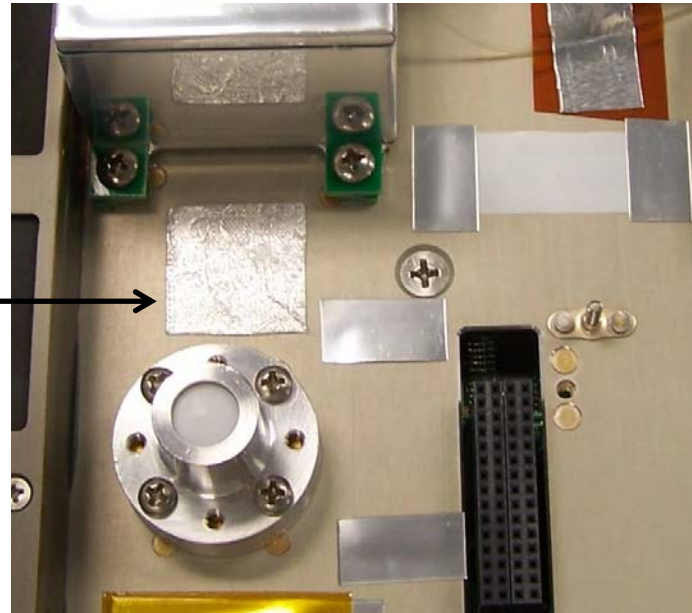


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Thermal control coatings

- AZ Technology RM550 IB inorganic black coating
- AZ Technology AZ3700 low emittance coating with 966 adhesive backing



MISSE-7B		Preflight	Postflight	$\Delta$	Environment
RM550IB	$\alpha$	0.974	0.974	-	3,200 ESH
	$\epsilon$	0.90	0.90	-	2.9E20 O atoms/cm <sup>2</sup>
AZ-3700	$\alpha$	0.28	0.26	-0.02	3,200 ESH
	$\epsilon$	0.31	0.38	+0.07	2.9E20 O atoms/cm <sup>2</sup>



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B

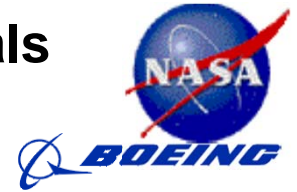


- Anodized Aluminum Results**

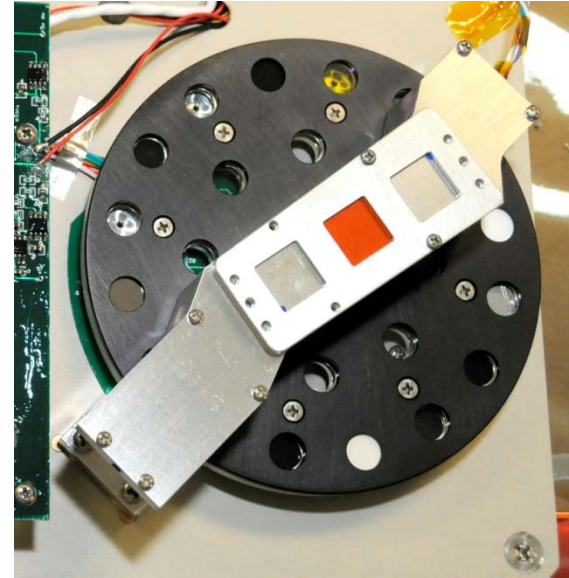
		Preflight	Postflight	$\Delta$	Environment
<b>MISSE-6 SAA on 6061-T6 #1 Hot deionized water seal</b>	$\alpha$	<b>0.44</b>	<b>0.43</b>	<b>-0.01</b>	<b>2,600 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.85</b>	<b>-</b>	<b>2.0E21 O atoms/cm<sup>2</sup></b>
<b>MISSE-6 SAA on 6061-T6 #2 Hot deionized water seal</b>	$\alpha$	<b>0.43</b>	<b>0.43</b>	<b>-</b>	<b>1,950 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.85</b>	<b>-</b>	<b>1.2E20 O atoms/cm<sup>2</sup></b>
<b>MISSE-7B SAA on 6061-T6 Ram side baseplate</b>	$\alpha$	<b>0.48</b>	<b>0.52</b>	<b>+0.04</b>	<b>4,500 ESH</b>
	$\epsilon$	<b>0.87</b>	<b>0.87</b>	<b>-</b>	<b>4.2E21 O atoms/cm<sup>2</sup></b>
<b>MISSE-7B SAA on 6061-T6 Wake side baseplate</b>	$\alpha$	<b>0.49</b>	<b>0.53</b>	<b>+0.04</b>	<b>3,200 ESH</b>
	$\epsilon$	<b>0.87</b>	<b>0.87</b>	<b>-</b>	<b>2.9E20 O atoms/cm<sup>2</sup></b>
<b>MISSE-7B SAA on 6061-T6 Sample tray</b>	$\alpha$		<b>0.43</b>		<b>3,200 ESH</b>
	$\epsilon$		<b>0.83</b>		<b>2.9E20 O atoms/cm<sup>2</sup></b>



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- **Anodized Aluminum Results**
  - **Black dyed sulfuric acid anodize used on carousels**



MISSE-7B		Preflight	Postflight	$\Delta$	Environment
Ram carousel	$\alpha$	0.71	0.70	-0.01	4,500 ESH
	$\epsilon$	0.86	0.87	+0.01	4.2E21 O atoms/cm <sup>2</sup>
Wake carousel	$\alpha$	0.69	0.68	-0.01	3,200 ESH
	$\epsilon$	0.86	0.86	-	2.9E20 O atoms/cm <sup>2</sup>



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Chemical conversion coating

- Alodine 5700 chrome-free

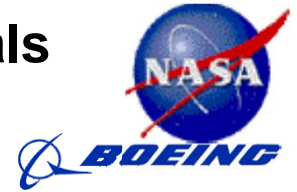


Alodine 5700		Pre-exp	Post-exp	$\Delta$	Environment
Control	$\alpha$	0.21	0.21	-0.01	-
	$\epsilon$	0.03	0.03	-	-
MISSE-7B Ram	$\alpha$	0.21	0.16	-0.05	4,500 ESH
	$\epsilon$	0.03	0.03	-	4.2E21 O atoms/cm <sup>2</sup>
MISSE-7B Wake	$\alpha$	0.20	0.18	-0.02	3,200 ESH
	$\epsilon$	0.03	0.04	+0.01	2.9E20 O atoms/cm <sup>2</sup>





# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- Chemical conversion coating

- Boegel chrome-free



Alodine 5700		Pre-exp	Post-exp	$\Delta$	Environment
Control	$\alpha$	0.18	0.18	-	-
	$\epsilon$	0.03	0.03	-	-
MISSE-7B Ram	$\alpha$	0.18	0.14	-0.04	4,500 ESH
	$\epsilon$	0.03	0.03	-	4.2E21 O atoms/cm <sup>2</sup>
MISSE-7B Wake	$\alpha$	0.18	0.22	+0.04	3,200 ESH
	$\epsilon$	0.03	0.03	+0.01	2.9E20 O atoms/cm <sup>2</sup>

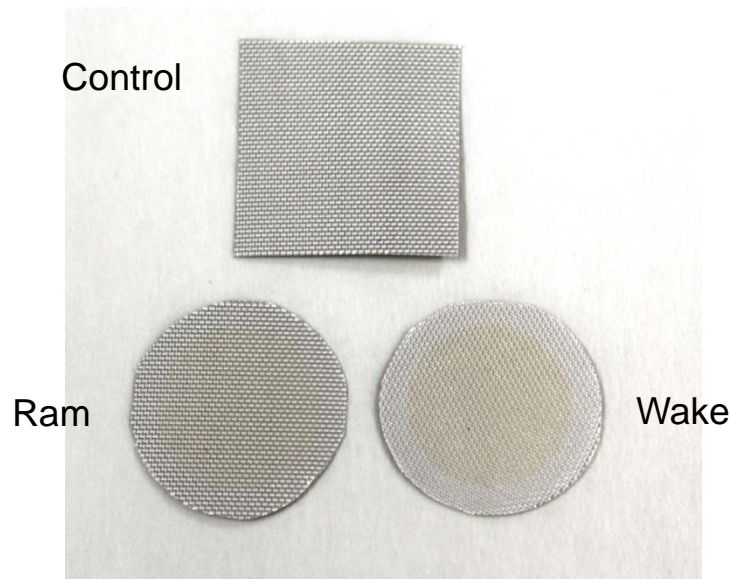


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## Beta Cloth

- Chemglas 500F is the same glass weave and Teflon as used in ISS insulation blankets
- Proprietary black coating used instead of aluminization for light blocking layer
- Samples flown on both ram and wake, white side and black side





# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## MISSE-7B Results for Chemglas 500F B/W Beta Cloth

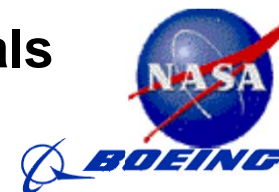
		Pre-exp	Post-exp	$\Delta$	Environment
White side ram facing	$\alpha$	0.42	0.43	+0.01	4,500 ESH
	$\epsilon$	0.89	0.89	-	4.2E21 O atoms/cm <sup>2</sup>
White side wake facing	$\alpha$	0.41	0.44	+0.03	3,200 ESH
	$\epsilon$	0.89	0.88	-0.01	2.9E20 O atoms/cm <sup>2</sup>
Black side ram facing	$\alpha$	0.97	0.93	-0.04	4,500 ESH
	$\epsilon$	0.88	0.89	+0.01	4.2E21 O atoms/cm <sup>2</sup>
Black side wake facing	$\alpha$	0.97	0.96	-0.01	3,200 ESH
	$\epsilon$	0.88	0.88	-	2.9E20 O atoms/cm <sup>2</sup>

**White side beta cloth results approx. the same change as previous MISSEs with and without aluminization**

All measurements made with black background



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## MISSE Results for Metallized Teflon

		Preflight	Postflight	$\Delta$	Environment
<b>10 mil Ag / Teflon Ram facing</b>	$\alpha$	<b>0.09</b>	<b>0.10</b>	<b>+0.01</b>	<b>4,500 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.85</b>	<b>-</b>	<b>4.2E21 O atoms/cm<sup>2</sup></b>
<b>10 mil Ag / Teflon Wake facing</b>	$\alpha$	<b>0.09</b>	<b>0.09</b>	<b>-</b>	<b>3,200 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.85</b>	<b>-</b>	<b>2.9E20 O atoms/cm<sup>2</sup></b>
<b>10 mil Ag / Teflon with 966 adhesive Ram facing</b>	$\alpha$	<b>0.08</b>	<b>0.09</b>	<b>+0.01</b>	<b>4,500 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.86</b>	<b>+0.01</b>	<b>4.2E21 O atoms/cm<sup>2</sup></b>
<b>10 mil Ag/Teflon with 966 adhesive Wake facing</b>	$\alpha$	<b>0.08</b>	<b>0.09</b>	<b>+0.01</b>	<b>3,200 ESH</b>
	$\epsilon$	<b>0.85</b>	<b>0.86</b>	<b>+0.01</b>	<b>2.9E20 O atoms/cm<sup>2</sup></b>



## Results of International Space Station Vehicle Materials Exposed on MISSE-7B



### **Indium Tin Oxide / Kapton / Aluminum**

- **Two different resistivities flown on wake side**
- **Negligible mass change for both samples**
- **Flight sample labeled 1500 ohms/square still measures 1570 – 1610 ohms/square post-flight**
- **Flight sample labeled 20K ohms/square now measures 2 – 3M ohms/square post-flight, as do the control samples.**
- **Original sheet materials that the control and flight samples were cut from still measure 1500 and 20K ohms/square, respectively**



## Results of International Space Station Vehicle Materials Exposed on MISSE-7B

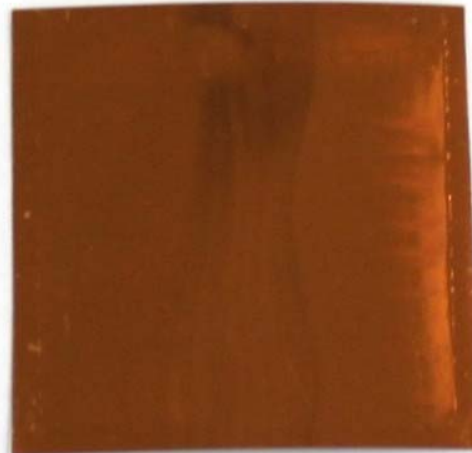


### Indium Tin Oxide / Kapton / Aluminum

- Discussed with Multek/Sheldahl personnel why control samples degraded as well.
  - Could be microcracking due to handling
  - 1500 ohms/square sample would have thicker ITO layer
  - 2 – 3M ohms/square still considered static dissipative



1500 ohms/sq



20K ohms/square

ITO / Kapton / Al

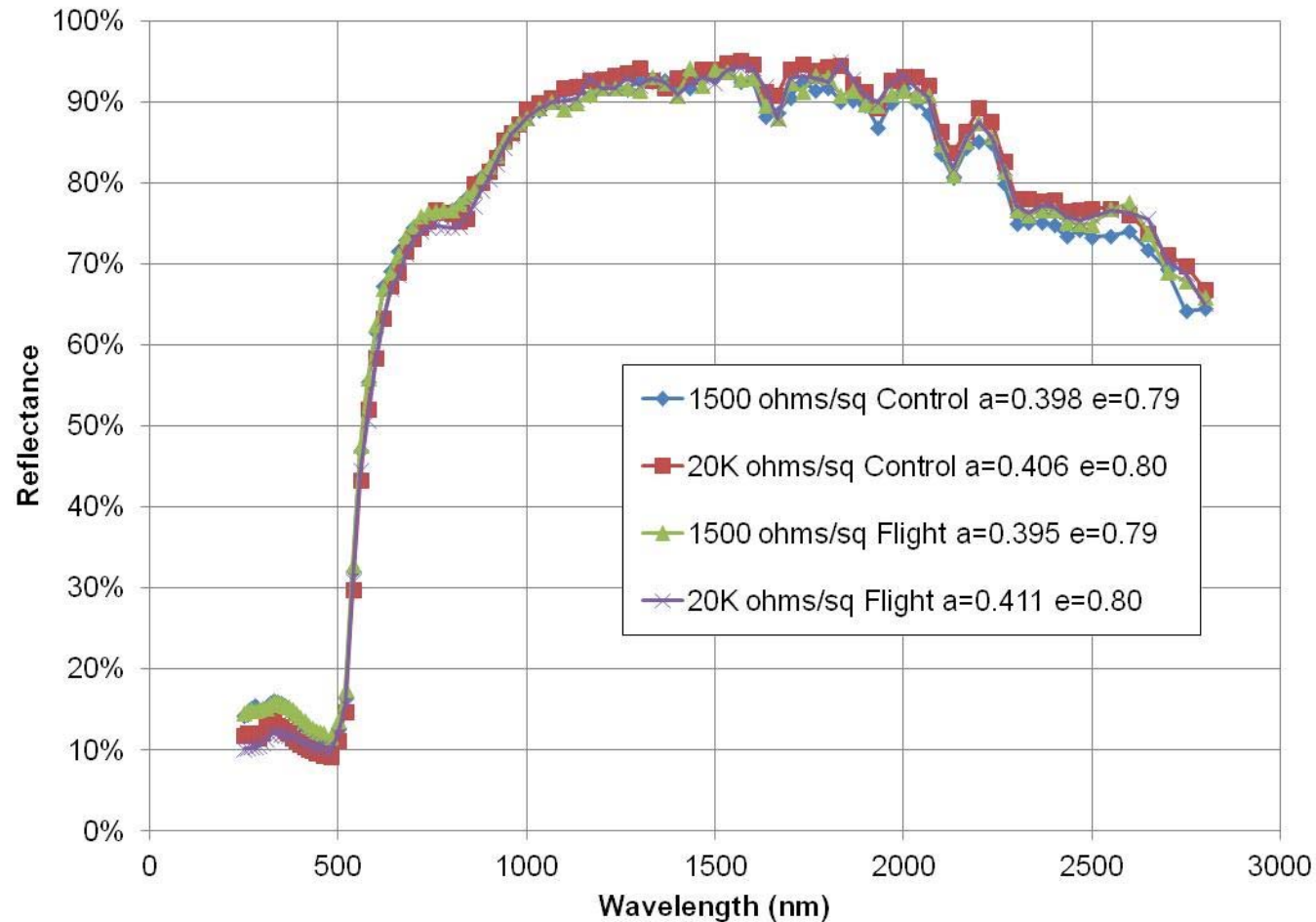




# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## MISSE-7B ITO / Kapton / Al





## Results of International Space Station Vehicle Materials Exposed on MISSE-7B



### Germanium / black Kapton and Stamet / black Kapton

- Stamet was developed by Astral Technology to have the same properties as germanium except better corrosion resistance and less RF attenuation
- Stamet Resistivity appeared to be slightly higher, 7.0 to 7.3 E7 ohms/square preflight to 8.0 to 8.9 E7 ohms/square postflight

		Pre-exp	Post-exp	$\Delta$	Environment
Germanium/ black Kapton - Wake	$\alpha$	0.47	0.47	-	3,200 ESH
	$\epsilon$	0.84	0.85	+0.01	2.9E20 O atoms/cm <sup>2</sup>
Stamet/black Kapton Ram	$\alpha$	0.48	0.49	+0.01	4,500 ESH
	$\epsilon$	0.84	0.84	-	4.2E21 O atoms/cm <sup>2</sup>
Stamet/black Kapton Wake	$\alpha$	0.48	0.49	+0.01	3,200 ESH
	$\epsilon$	0.84	0.85	+0.01	2.9E20 O atoms/cm <sup>2</sup>

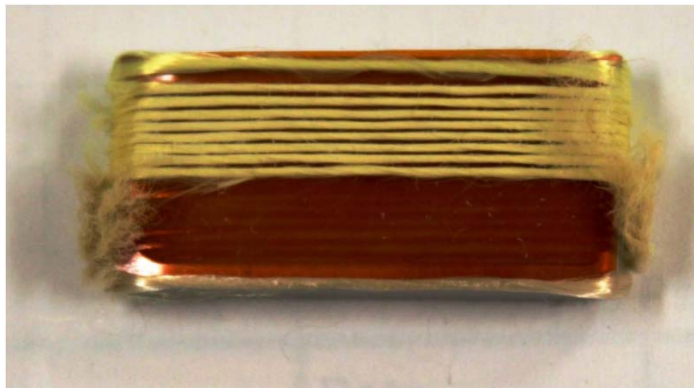


# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



## Kevlar and Vectran

- Both yarn and cable materials flown on ram and wake sides
- Vectran yarn on ram side did not survive the exposure, but the cable only darkened, likely due to finish or sizing.
- Kapton flown underneath, can determine AO fluence to erode through Vectran (analysis continuing).



**Ram**



**Wake**

**Kevlar yarn on top, Vectran yarn on bottom**

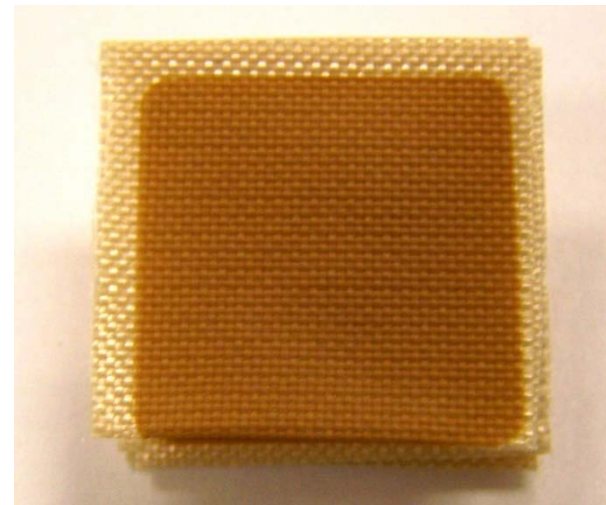


## Results of International Space Station Vehicle Materials Exposed on MISSE-7B



### Kevlar and Vectran

- Previously flown on MISSE-1, -2, and -4 were samples of Kevlar webbing, Kevlar felt, and Vectran HS with T150 finish, which is oil added to aid weaving.
- Vectran cables flown on MISSE-7B appears to have similar finish, which prevented AO erosion.



Left, top to bottom, ram-facing Kevlar cable, Kapton witness film, Vectran cable. Kevlar is eroded, Vectran is only UV-darkened. Compare to MISSE-1 Vectran on right.



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- **Summary**

- **Provided data for sustaining engineering of ISS**

- **White and black thermal control coatings maintained optical properties**
- **Still having trouble with consistent sulfuric acid anodizing**
  - ◆ **Hot water seal is still recommended**
- **Chrome-free chemical conversion coatings showed some degradation, as did the beta cloth with black backing exposed**
- **Lower resistivity ITO/Kapton more durable in LEO**
- **Germanium/black Kapton and Stamet/black Kapton showed durability**

- **Contamination control plan working**

- **Most darkening due to UV degradation, not contaminant deposition**



# Results of International Space Station Vehicle Materials Exposed on MISSE-7B



- **MISSE-8 on ISS now**
  - **Continue contamination monitoring with optical witness samples**
  - **Indium tin oxide on Kapton**
  - **ITO / SiO<sub>x</sub> / Kapton**
  - **Permacel and Intertape protective fiberglass tapes on Kapton**
  - **Fiberglass sleeve material**
  - **Solar array scrim cloth**
  - **Sheldahl G4280 glass cloth**
  - **Environmentally-friendly chemical conversion coatings**





# Results of International Space Station Vehicle Materials Exposed on MISSE-7B

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- **Acknowledgements**

- **Special thanks to:**

- **Julie Henkener, system manager, Rajib Dasgupta, previous system manager, and Dr. John Alred, deputy system manager for ISS M&P**
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    - **Susie LaCava of the Naval Research Laboratory for pre-flight photos.**
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